Measurement of Ocean Spatial Coherence by Spaceborne Synthetic Aperture Radar

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LONG-TERM GOAL

The long term goal of this work is specify long ocean wave spatial coherence in a way that is useful for designers of Mobile Offshore Bases (MOBs). The proposed sizes of MOBs are on the order of a kilometer or more and pose unique design challenges. In particular, we intend to generate a statistical database of wave "long-crestedness" and "groupiness" from spaceborne synthetic aperture radar (SAR) imagery of the ocean surface. We will place emphasis on those SAR images in high sea states, the environmental conditions that will pose the greatest challenge to MOBs. SAR images from hurricanes will likely prove the most useful.

APPROACH

In August 1997, the Office of Naval Research (ONR) hosted a workshop entitled "Spatial Coherence of Wave Phenomena: Information for Mobile Offshore Base Design" [1]. The purpose of this workshop was to explore existing observational data sets that might provide key information on the spatial coherence of ocean waves. The workshop underscored the importance of understanding the coherence of the ocean waves in terms of wave groups, lengths of wave crests, and nonlinearity. The workshop report specifically lamented that "there is little data of definitive use at the scales relevant for the MOB."

This work addresses this serious lack of observational data by using the enormous archive of SAR ocean imagery acquired by the Shuttle Imaging Radar (SIR-C) as well as a large collection of Radarsat and ERS-1/2 imagery.

Spaceborne SAR imagery of ocean waves is aptly suited to addressing important questions surrounding wave spatial coherence. SAR images typically have resolutions of 25 to 30 m with swath lengths of hundreds of kilometers and swath widths from 25 km to over 100 km. Radarsat and ERS-1/2 are operational satellites with large archives of ocean imagery. SIR-C imagery is particularly useful since image fidelity is optimal at the low altitude flown by the shuttle [2]. Using SAR imagery, one infers the wavelength and direction of long ocean surface waves, and by using various autocorrelation procedures, the length of wave crests and wave "groupiness" can also be estimated [3].

The approach used here is:

- To collate available SAR imagery suitable for the measurement of long waves relevant to the MOB. Significant sets of SIR-C, Radarsat, and ERS-1/2 imagery are already in house at Johns Hopkins APL.
- To refine and implement autocorrelation techniques to extract wave crest lengths and groupiness parameters from the imagery.
- To produce climatologies of the statistics on wave groupiness and long wave crest lengths from available imagery.
- To support field tests with co-located SAR imagery.

WORK COMPLETED

Thus far we have completed an inventory of SAR wave imagery suitable for this work. These data are composed of imagery from the SIR-C, Radarsat, and ERS-1 and ERS-2. We have image of five hurricanes, including one imaged during SIR-C at an optimum imaging altitude. Table 1 is a listing of these data.

Table 1: Partial listing of SAR ocean wave imagery at APL useful for measuring wave coherence. We anticipate the availability of additional data as satellites continue acquire SAR imagery.

SIR-C at 25 m resolution and C and L-band, dual polarization
Nine data takes in the North Atlantic at two frequencies and HH and VV polarizations.
SIR-B at 25 m resolution and L-band HH polarization
Hurricane Josephine.
SIR-C at 80 m resolution and L-band HH polarization
4 Southern Ocean Data Takes, 33 Gulf Stream Data Takes
ERS-2 at 25 m resolution and C-band VV polarization
Hurricanes Edouard.
Radarsat at 25 m resolution and C-band and HH polarization
Hurricanes Edouard and Hortense.
Radarsat at 100 m resolution and C-band and HH polarization
Hurricanes Bonnie and Danielle.

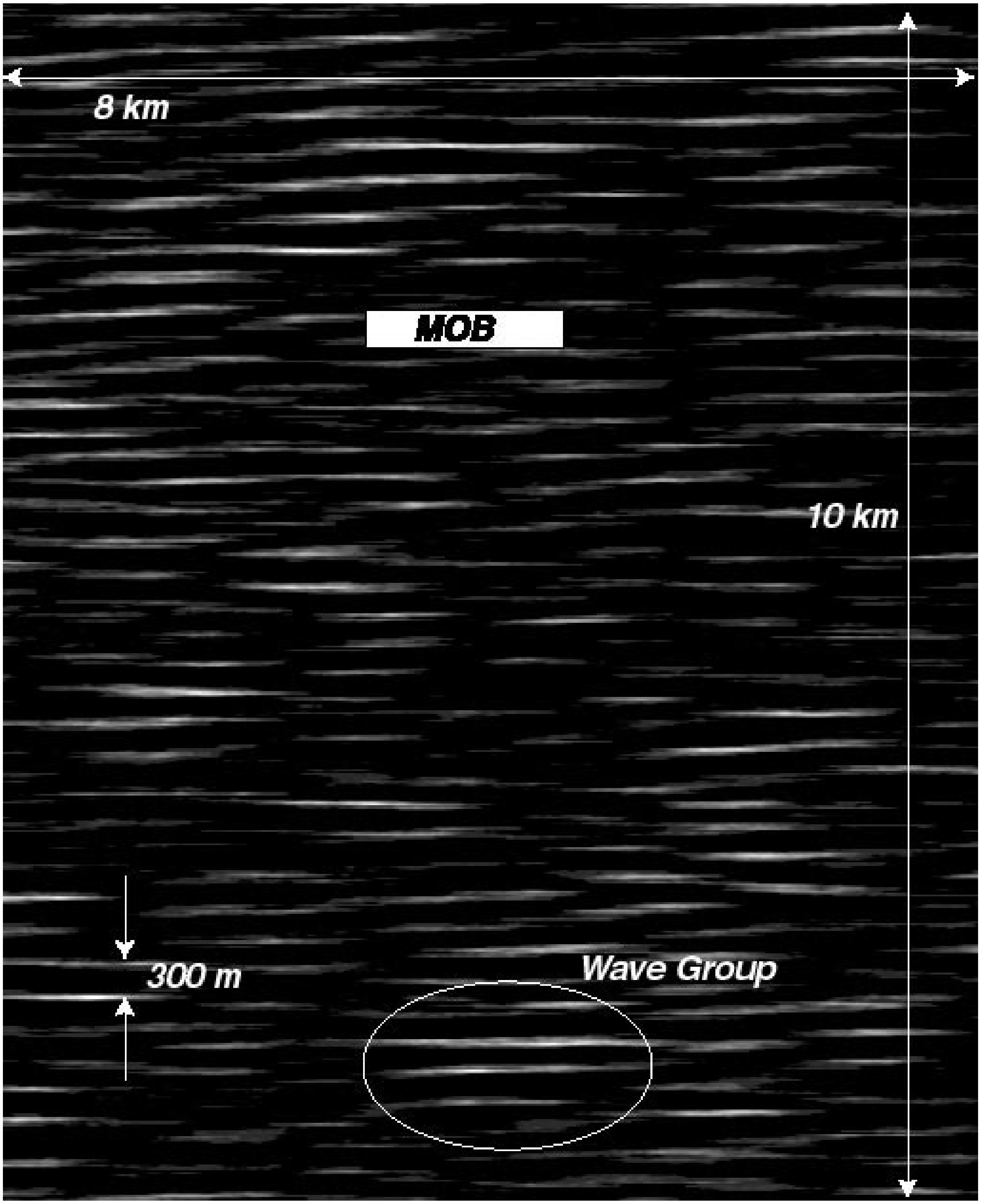

Figure 1 This image is derived from Radarsat imagery in the vicinity of Hurricane Edouard. A notional MOB platform 1.6 km long and 500 m wide is shown. Wave crests separated by 300 m are show in the lower left-hand corner. We also indicate a wave group near the bottom of the image.

RESULTS

The first step in extracting useful wave coherence information from these images is the development of statistical tools to automatically characterize wave coherence parameters. Figure 1 is an example of how SAR imagery provides useful information to MOB designers. The background SAR image is a Radarsat image of long ocean wave from propagating in from Hurricane Edouard in 1996. To produce this image we applied a running average of 1 km in length in the horizontal direction and then set a threshold to enhance the bright features. The relationship of wave crests to the MOB is apparent.

As a first step at assessing long crestedness, we used the above image and measured by hand the crest lengths. Ultimately we will implement automated procedures to perform this task. Nonetheless, this image reveals a first estimate of long crestedness. Figure 2 is a plot of the probability of a particular crest length as function of crest length. Note that for the dominant 300 m wavelength wave system, the most probable crest length is about 800 m. By processing enough imagery, we intend to estimate typical crest length as a function of dominant wavelength.

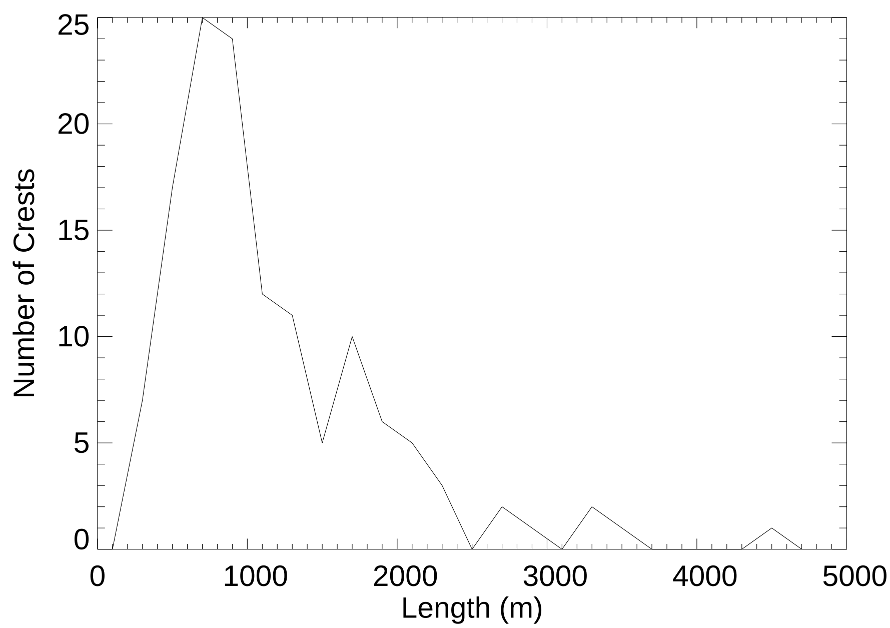

Figure 2: Probability density function of crest length for SAR imagery from Hurricane Edouard.

IMPACT / APPLICATION

The fact that this program has just begun limits the current impact of this work. Clearly, the anticipated impact is the production of wave coherence statistics that will make possible more realistic designs for MOBs.

RELATED PROJECTS

Synthetic Aperture Radar Imagery of the Ocean Surface During the Coastal Mixing and Optics Experiment, Donald Thompson and David Porter.

REFERENCES

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3. Phillips, O. M., D. Gu, and M. Donelan, Expected structure of extreme waves in a Gaussian sea. Part I: Theory and SWADE Measurements, *J. Phys. Oceanog.*, *23*, 922–1000, 1993.